

Molybdate toxicity and sulfur and nitrogen metabolism in Chinese cabbage

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Molybdenum (Mo) is an essential micronutrient for plant growth, which requirement is the lowest of all mineral nutrients. Mo is taken up by the root as molybdate and incorporated into molybdopterin-cofactor (Moco). This cofactor is essential for the activity of nitrate reductase, sulfite oxidase, aldehyde oxidase and xanthine dehydrogenase. High concentrations of molybdate in the root environment may negatively affect plant growth, though the physiological basis for its phytotoxicity is largely unsolved. Mo is sometimes described as a 'heavy metal', though it appears to be much less phytotoxic than other potential toxic metals *viz.* copper and zinc. If Chinese cabbage (*Brassica pekinensis*) seedlings were exposed 50, 100, 150 and 200 μM sodium molybdate, leaf chlorosis and a decreased plant biomass production occurred at $\geq 100 \mu\text{M}$. Root growth was relatively more affected by molybdate than shoot growth. Exposure resulted strongly enhanced Mo contents of the plant, but it only substantially affected the overall mineral nutrient composition of root and shoot at 200 μM . It is presumed that high concentrations of molybdate as chemical analogue might negatively interfere with the uptake and reduction of sulfate in plants. However, molybdate exposure of Chinese cabbage resulted in an increase in sulfate uptake at $\geq 100 \mu\text{M}$ and to a lesser extent also that nitrate, though only when expressed on a root fresh weight basis and not on a plant fresh weight basis. Similarly, there was an increase sulfate uptake capacity (activity of the sulfate transporters) but again only expressed a root fresh weight basis. However, the expression of the sulfate transporter Sulfr1;2, which is the primary transporter for the uptake of sulfate by the root, was decreased at $\geq 100 \mu\text{M}$. Molybdate exposure did not affect the nitrate reductase activity, whereas total nitrogen and nitrate content were decreased in both roots and shoot but only at 200 μM . The total sulfur, sulfate and water-soluble non-protein thiol

(GSH) content and the expression of APS reductase, the key regulating enzyme of the sulfate reduction pathway, in both root and shoot were hardly affected upon molybdate exposure. There was only a slight increase in the sulfate content at 200 μ M. In conclusion, Mo toxicity in Chinese cabbage was unlikely directly due to the direct interference of molybdate with sulfate uptake and its assimilation.